HURRICANE-INDUCED TORNADOES AND THEIR DISTRIBUTION

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ABSTRACT

The 39 tornado occurrences associated with the four hurricanes which struck the United States during 1964 are shown to favor a location in the right front quadrant of the storm. A distribution of hurricane tornadoes over the past 10 yr. is presented, also favoring the right front quadrant. Some suggestion of a preference for afternoon formation is rejected because a time bias was noted in reports from hurricane Isabell.

1. INTRODUCTION

The reporting of tornadoes associated with hurricanes has, by necessity, depended upon the frequency of hurricanes and their proximity to a suitable reporting network. Tannehill [1] noted that few authentic records existed of tornadic storms during hurricanes. Malkin and Galway [2] presented data showing only 24 reported tornadoes over a 141-yr. period ending in 1962. Sadowski [3] showed that the 15 tornadoes accompanying hurricane Carla favored a location to the right of the hurricane's direction of motion. In the most comprehensive study Smith [4] presented 98 tornado occurrences between 1955 and 1961 (including hurricane Carla in 1961), and found that 56 percent of the reported tornadoes were located in a pie-shaped area, to the right of the direction of movement (fig. 1). Whereas Malkin and Galway had found no significant correlation between tornadic occurrences and time of day, Smith stated that the most favorable time period was from 0900 to 2100 GMT (0400–1600 EST).

Hurricane activity affecting the United States was at a minimum in 1962 and 1963 and no new hurricane-tornado occurrences were recorded. The 1964 season began slowly but by November 1 four hurricanes had struck the United States accompanied by 39 tornadoes. Of the 49 fatalities attributed to the hurricanes, 28, or 57 percent, resulted from the tornadoes. It became apparent to hurricane forecasters that further reductions in the death toll might be achieved if more were known about the hurricane tornado. That progress had been made was shown by the Weather Bureau's Severe Local Storm Forecast Center at Kansas City. Utilizing improved procedures they were successful in forecasting the time of occurrence of 43 percent of the tornadoes that occurred in 1964 within their forecast areas, including 13 of the 17 associated with hurricane Isbell.

2. 1964 OCCURRENCES

The 1964 occurrences are shown in figure 2. The numbering coincides with the tabulation in table 1. Smith's favored area has been transferred from figure 1 for ease of reference. It is readily apparent that differences exist, for the point of emphasis has visually shifted counterclockwise by 40°. The four storm tracks of 1964 were plotted (fig. 3) to determine if this is due to the data sample.

Cleo approached southern Florida from the south-southeast. After passing over Miami the center followed the eastern coast of Florida and Georgia before turning northwestward and weakening. During most of this period the right front and right rear quadrants were predominantly over the Atlantic Ocean except for a narrow coastal strip from Miami to Daytona Beach. Only 2 of the 12 tornadoes were reported during this period, and they were directly ahead of the storm's path. A reporting bias is evident, favoring the left quadrants.

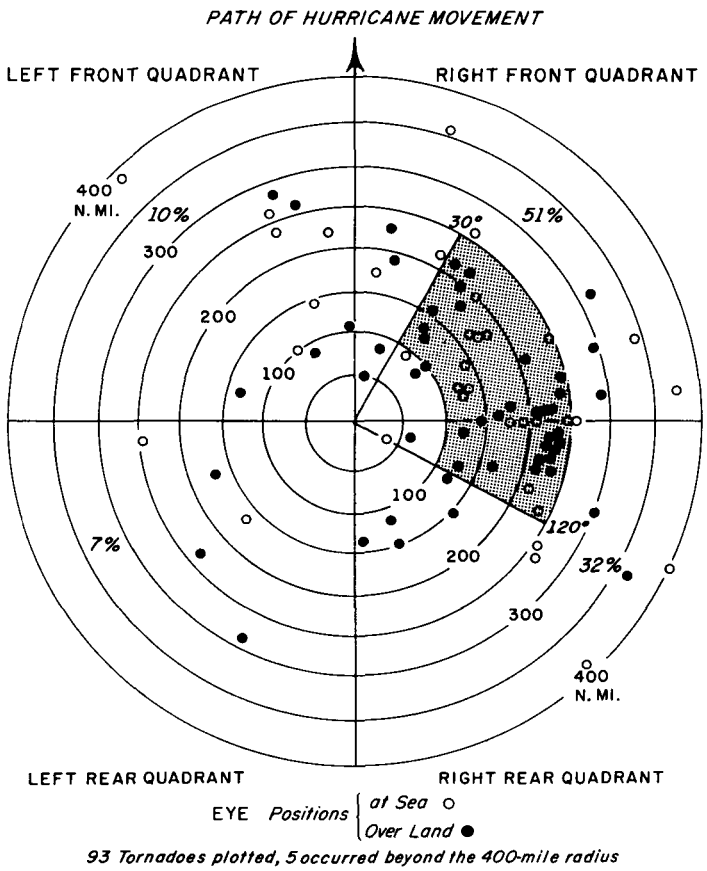

FIGURE 1.—Tornadoes associated with hurricanes during 1955–1962 located with reference to center and direction of movement of the hurricanes. (From Smith [4].)

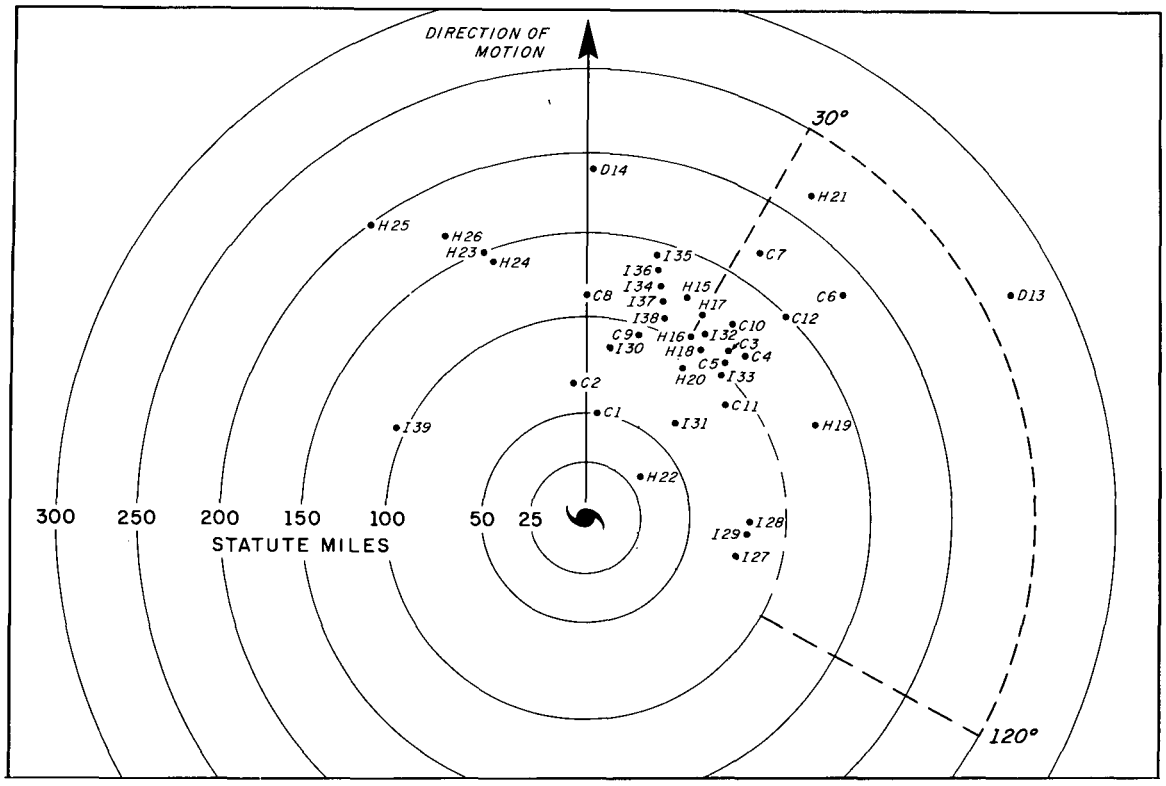

FIGURE 2.—Tornadoes associated with hurricanes in 1964 located with reference to center and direction of movement of the hurricanes. The dashed sector corresponds to the stippled area in figure 1.

TABLE 1.—*Tornadoes associated with hurricanes in 1964. In the No. column, the combination of letter and number corresponds to the labeling in figure 2. The letter denotes the hurricane; C=Cleo, D=Dora, H=Hilda, and I=Isbell*

No.	Date	Time	Place	Tornado distance and azimuth from eye		Location of hurricane eye
				(mi.)	(deg.)	
C-1	8-27	1900 EST	Titusville, Fla	50	05	Center over land, 10 mi. from east coast of Fla.
C-2	8-27	2010 EST	New Smyrna Beach, Fla	65	355	Center over land, 5 mi. from east coast of Fla.
C-3	8-29	0106 EST	5 mi. S Charleston, S.C	112	40	Center over land in coastal Ga.
C-4	8-29	0125 EST	10 mi. SSE Charleston, S.C	115	45	Center over land in coastal Ga.
C-5	8-29	0440 EST	30 mi. NNE Charleston, S.C	110	40	Center over land in coastal Ga.
C-6	8-29	1045 EST	Myrtle Beach, S.C	185	50	Center over land in coastal area near Ga.-S.C. border.
C-7	8-29	1440 EST	Laurinburg, N.C	170	33	Center over land just N Savannah, Ga.
C-8	8-29	1600 EST	14 mi. NW Columbia, S.C	115	00	Center over land just N Savannah, Ga.
C-9	8-29	aftn.	38 mi. WNW Florence, S.C	95	16	Center over land just N Savannah, Ga.
C-10	8-29	2130 EST	Darlington, S.C	125	38	Center over land in southern S.C.
C-11	8-29	2359 EST	12 mi. SW Florence, S.C	90	50	Center over land in southern S.C.
C-12	8-30	0400 EST	Laurinburg, N.C	150	45	Center over land in S.C.
D-13	9-12	2100 EST	Howell's Point, N.C	270	62	Center over land in Ga. near S.C. border
D-14	9-13	0700 EST	Carteret Co., N.C	190	02	Center over land in eastern S.C.
H-15	10-3	Before 0600 CST	Larose, La., Galliano, La	118	25	Eye over Gulf, 75 mi. off coast
H-16				106	30	
H-17	10-3	0630 CST	35 mi. SSW New Orleans, La	112	32	Eye over Gulf, 70 mi. off coast
H-18	10-3	0730 CST	Golden Meadow, La	103	35	Eye over Gulf, 65 mi. off coast
H-19	10-3	0900 CST	New Orleans, La	130	68	Eye over Gulf, 55 mi. off coast
H-20	10-3	1110 CST	60 mi. W New Orleans, La	97	32	Eye over Gulf, 50 mi. S of Pt. Au Fer
H-21	10-3	1520 CST	Poplarville, Miss	218	35	Eye over Gulf, 15 mi. WSW of Pt. Au Fer
H-22	10-4	0325 CST	30 mi. N New Orleans, La	55	30	Center over land, 10 mi. E of Baton Rouge, La.
H-23	10-4	1020 CST	Georgiana (55 SSW Montgomery), Ala	150	339	Center over land, 80 mi. NE New Orleans, La.
H-24	10-4	1024 CST	6 mi. NE Evergreen, Ala	145	340	Center over land, 80 mi. NE New Orleans, La.
H-25	10-4	1630 CST	Crawford, Ala	200	325	Center over land, 25 mi. ENE Mobile, Ala.
H-26	10-4	1630 CST	Eufaula, Ala	170	335	Center over land, 25 mi. ENE Mobile, Ala.
I-27	10-14	1515 EST	5 mi. SE Homestead, Fla	78	105	Eye over water, 18 mi. SW of Everglades City
I-28	10-14	1540 EST	Coral Gables, Fla	81	90	Eye over water, 12 mi. SW of Everglades City
I-29	10-14	1556 EST	7 mi. S Miami, Fla	80	93	Eye over water, 8 mi. WSW of Everglades City
I-30	10-14	1722 EST	Lantana Airport, Fla	85	10	Eye over land, 18 mi. N of Everglades City
I-31	10-14	1750 EST	Fort Lauderdale Arpt., Fla	62	44	Eye over land, 25 mi. NNE of Everglades City
I-32	10-14	aftn.	15 mi. S West Palm Beach	112	32	Used 1500 EST eye position; eye over water, 30 mi. SW of Everglades City.
I-33	10-14	aftn.	29 mi. S West Palm Beach	105	40	
I-34						
I-35			The 5 tornadoes occurred in east coast counties from Coral Gables N'ward to Melbourne. Midpoint, Jupiter, was used as average location for 5 tornadoes.	Ave. 125	20	Used 1500 EST eye position and mid-afternoon or midpoint location; eye over water, 30 mi. SW of Everglades City.
I-36	10-14	aftn.				
I-37						
I-38						
I-39	10-14	2020 EST	W of Eau Gallie, Fla	105	295	Eye over land, 20 mi. W of West Palm Beach, Fla.

This was not the case with Dora, for the center approached the shoreline on a perpendicular course. The four quadrants of the storm passed over land and over a dense reporting network. Only two tornadoes were reported with Dora.

Hilda was moving toward the north when the center

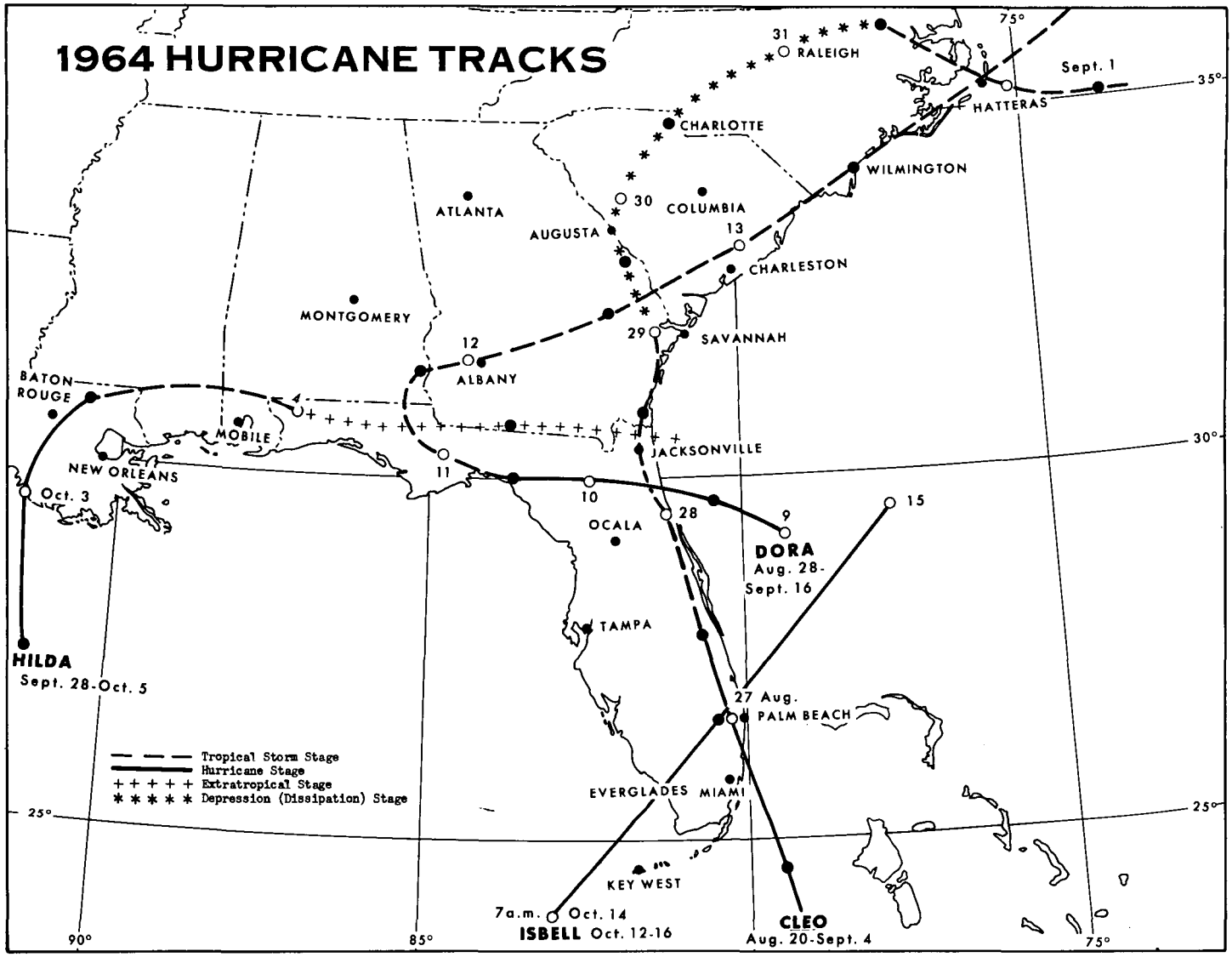

FIGURE 3.—Tracks of hurricanes Cleo, Dora, Isbell, and Hilda, 1964.

crossed the central Louisiana coastline. Recurvature took place after the major tornadic outbreak; 12 in all were reported. The four quadrants of the storm were all over land and no reporting bias is evident.

Isbell was the smallest and least severe of the storms that struck the United States in 1964, but it had most of the hurricane-tornadoes reported in 1964. The center passed inland on a northeasterly track near Everglades City, Fla., and moved out to sea near West Palm Beach, Fla. Although the entire storm was technically over a reporting network, the right front and right rear quadrants passed over a densely populated reporting network along the eastern Florida coastal strip while the left front and left rear quadrants were over the Everglades Swamp a majority of the time. Only one of the 17 tornadoes was reported in the left quadrants and not until the left front quadrant was over the West Palm Beach area.

This strongly suggests that the overall data sample from the four storms was randomly distributed, and does not overly favor any particular quadrant of the storm as a result of the associated reporting network.

A histogram of time of occurrence is shown in figure 4. The 7 tornadoes with Isbell, for which the specific time was not known, have been distributed equally between the 12–3 and 3–6 p.m. classes. Malkin and Galway had not found any time preference but the 1964 data show a decided preference for the afternoon hours. While it has been established that the data sample is representative regarding spatial distribution, the same does not hold true for time. Hurricane Isbell produced the largest number of tornadoes, but because of the storm's small size and rapid forward speed, its influence over Florida was limited to a 12-hr. period from noon until midnight. The center went inland at 1600 EST and passed out into the Atlantic at 2210 EST. Removing the Isbell sample (fig. 4) lends support to Malkin and Galway's suggestion of no favored time period.

3. 1955–1964 DISTRIBUTION

Figure 5 includes the reported tornadoes of the past decade, utilizing the 98 occurrences noted by Smith and the 39 of 1964. It was not possible to include the 24

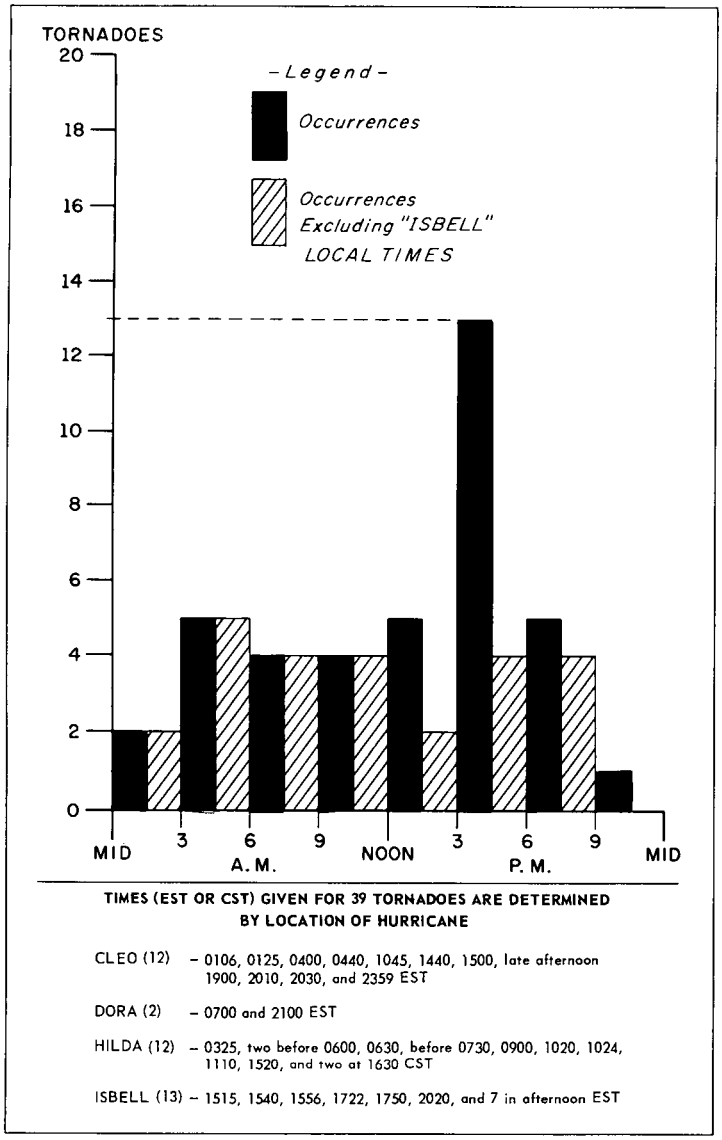

FIGURE 4.—Tornado occurrences distributed with reference to time of day (EST or CST) according to the time zone of location of associated hurricanes, 1964.

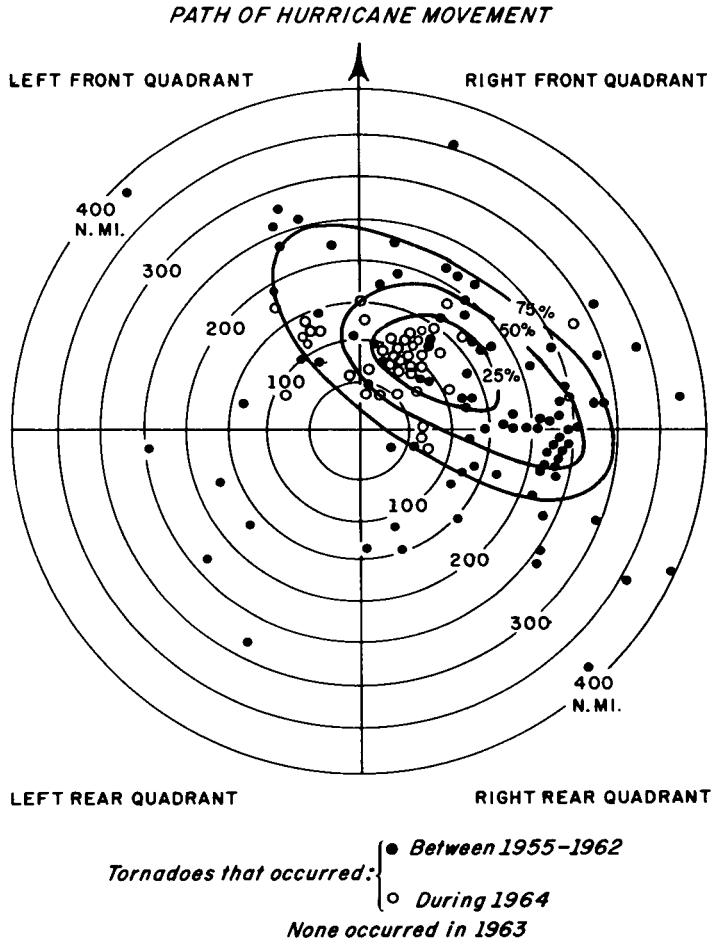

FIGURE 5.—Tornadoes associated with hurricanes during 1955–1964 located with reference to center and direction of movement of the hurricanes.

tornadoes reported by Malkin and Galway since the hurricane positions during the period of study could not be determined with sufficient accuracy. Isopleths enclose the areas containing 25, 50, and 75 percent of the data sample. The 75 percent isopleth should not be taken to mean that there is a 75 percent chance of a tornado occurring inside the area. It does mean that *if* a tornado does occur, there is a 75 percent chance of its occurring inside the area shown.

It is gratifying to note that the area of greatest concentration falls outside the general area of hurricane force winds. The mean radius of hurricane force winds during occurrences of tornadoes was 40 mi.

Forecasters have shown an understandable reluctance to superimpose tornado warnings on hurricane warnings, arguing that there was little more that the public could do about the tornado that they had not already done in preparing for the hurricane. Figure 5 shows that an outbreak of tornadoes could occur 6 to 12 hr. prior to the arrival of hurricane force winds, when lead time for emergency actions is still available. The grouping also suggests the general area where extra radar surveillance and aircraft investigative flights could well be expended.

ACKNOWLEDGMENTS

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